DOI: 10.1002/ejoc.201000807

Synthesis of Mono(perfluoroalkyl) Cyclodextrins via Cross Metathesis

Michal Řezanka,[a] Barbara Eignerová,[a,b] Jindřich Jindřich,*[a] and Martin Kotora*[a,b]

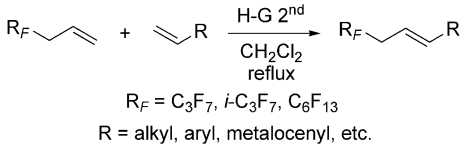
Keywords: Metathesis / Cyclodextrins / Fluorine / Alkylation / Amphiphiles

Ruthenium–carbene complex catalyzed cross metathesis of monoallyl α-, β-, and γ-cyclodextrins with perfluoroalkylpropenes resulted in the formation of the corresponding perfluoroalkylated cyclodextrins. The reactions proceeded under standard reaction conditions and yielded the desired compounds in reasonable yields. Dynamic light scattering measurements proved the ability of the prepared compounds to aggregate in water solution forming nanoparticles in the range of tens and thousands of nanometers.

Introduction

Organic molecules containing fluorine have been in the centre of scientific attention due to their potential activity in exploitation in biomedical research.[1] In this respect, compounds possessing perfluorinated chains often form vesicles and nanocapsules that are usually more stable and less permeable than their non-fluorinated analogs.[2,3] One class of such compounds are cyclodextrins (CDs), macrocyclic host compounds formed by α-1,4-linked D-glycopyranose units, and their amphiphilic derivatives that are of considerable interest for pharmaceutical applications in view of their ability to self-organize in water.[4–6]

Perfluoroalkylated chains have usually been attached to cyclodextrin via a sulfide bridge such as the case of monotrifluoromethyl,[7] perfluoroethyl,[8] and mono-, di-, tetra-, and polyperfluoroalkylated[9] cyclodextrins. Alternatively, an ester linkage has been applied.[10] Another option for attaching the perfluoroalkylated chains to various fragments is cross metathesis of two alkenes.[11,12] This approach has been recently applied for the synthesis of monoperfluoroalkylated cyclodextrins and was based on a ruthenium complex catalyzed reaction of perfluoroalkylethenes with (allylamino)cyclodextrin derivatives.[13] Recently, we have shown that perfluoroalkylation based on cross metathesis of alkenes (bearing alkyl, aryl, metalocene, sugar, terpenoid, etc. moieties) is more conveniently carried out with perfluoroalkylpropenes instead of perfluoroalkylethenes (Scheme 1). The former are easier to access, as a twofold molar excess with respect to the alkene substrate is enough to ensure high yields of cross metathesis, and the reaction could be carried out in commonly used dichloromethane.[14] This approach has been recently applied in the synthesis of fluorinated analogs of brassinosteroids[15] and carboranes.[16]



Scheme 1. Cross metathesis of perfluoroalkylpropenes with alkenes.

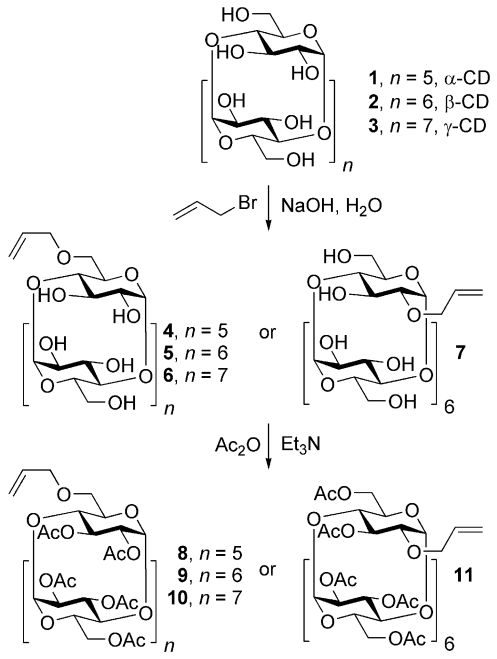
Derivatization of cyclodextrins could be carried out by two ways: (i) direct substitution of a cyclodextrin with a suitable functional group or (ii) transformation of a functional group on the attached chain on the cyclodextrin. The advantage of the latter approach is obvious: a selectively derivatized cyclodextrin undergoes further transformation on the side chain, avoiding problems associated with the functionalization to different positions on the cyclodextrin framework. In this regard, selectively allylated cyclodextrins in which the double bond could participate in further reactions are considered to be ideal starting substrates. Although some 6^{I}-*O*-allylcyclodextrins have been prepared,[17,18] there is no general preparative method available for these derivatives.

Herein we would like to report a general procedure for the preparation of perfluoroalkylated cyclodextrins by grafting a single hydrophobic anchor. The procedure is based on cross metathesis of perfluoroalkylpropenes with various monoallylated cyclodextrins and is an efficient method for the synthesis of monoperfluoroalkylated amphiphilic α-, β-, and γ-cyclodextrins. Moreover, selective allylation at the 6^{I}-*O*-positions has been solved. Dynamic light scattering measurements proved the ability of the prepared compounds to aggregate in water solution.

[a] Department of Organic and Nuclear Chemistry, Faculty of Science, Charles University in Prague, Hlavova 8, 12843 Praha 2, Czech Republic
Fax: +420-221-951-326
E-mail: kotora@natur.cuni.cz
[b] Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic, Flemingovo nám. 2, 16610 Praha 6, Czech Republic
Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/ejoc.201000807.

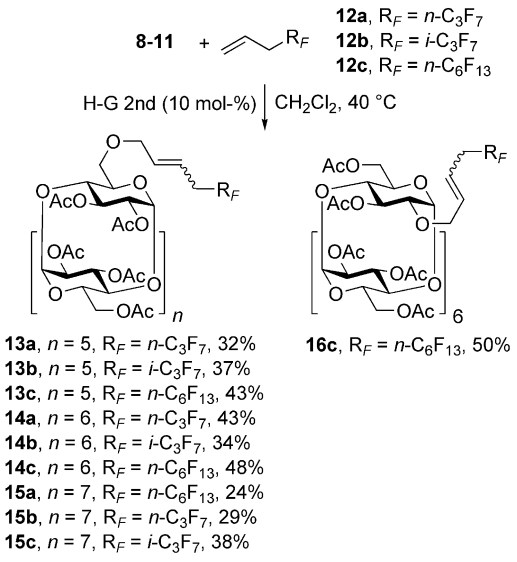
Results and Discussion

At the outset, *O*-allylcyclodextrins were prepared (Scheme 2). 2^{I}-*O*-Allyl-β-cyclodextrin **7** was prepared in 11% isolated yield by a previously described procedure[19] based on the selective allylation of cyclodextrin **1**. 6^{I}-*O*-Allylcyclodextrins were all prepared by a new general procedure based on the method for the preparation of 6^{I}-*O*-*p*-cyanobenzyl-β-cyclodextrin.[20] The procedure was carried out by reaction of cyclodextrin with allyl bromide in 8 M NaOH in water. The other regioisomers (2^{I}-*O*- and 3^{I}-*O*-allyl) were not detected under these conditions. The only byproducts detected were highly poly-6-*O*-allylated CDs. Allylcyclodextrin **4**[18] was prepared from **1** in 14% yield, **5**[17] was prepared from **2** in 17% yield, and newly synthesized **6** was prepared from **3** in 18% yield. Peracetylation of **5** to **9**[17] was carried out according to a previously reported procedure. Peracetylated cyclodextrins **8**, **10**, and **11** were synthesized under the same conditions. Yields of the peracetylation were nearly quantitative in all cases. Peracetylation of compounds **4**–**7** is necessary due to the very low solubility of compounds **12a**–**c** and catalysts in water or water/methanol mixtures.



Scheme 2. Preparation of starting allylcyclodextrins **8**–**11**.

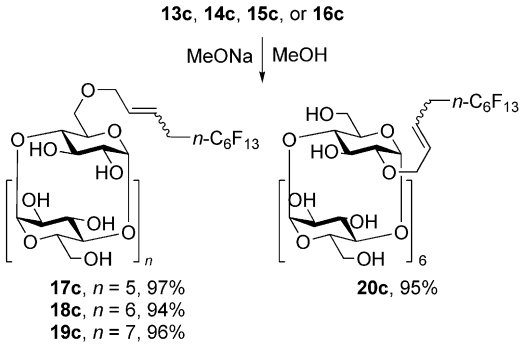
With the prepared allylcyclodextrins in hand, cross metatheses with various perfluoroalkylpropenes **12** were undertaken (Scheme 3). Branched and linear perfluoroalkylpropenes **12** with various chain lengths were selected to assess the generality of the reaction. Because we have recently shown that the cross metathesis of perfluoroalkylpropenes is efficiently catalyzed by Hoveyda–Grubbs second generation catalysts,[21] it was also used as a catalyst of choice. The reactions were run under standard conditions by heating the reactants and the catalyst (10 mol-%) at reflux in CH_2Cl_2 under a protective atmosphere of argon for 24 h. The cross metathesis of α-allylcyclodextrin **8** with perfluoropropyl- (**12a**), perfluoroisopropyl- (**12b**), and perfluorohexylpropene (**12c**) yielded the corresponding perfluoroalkylated α-cyclodextrins **13a**–**c** in reasonable 32, 37, and 43% isolated yield, respectively. By analogy, the reaction of β-allylcyclodextrin **9** with **12a**–**c** was also carried out. In this case, the yields of the corresponding perfluoroalkylated β-cyclodextrins **14** were also similar: **14a** (43%), **14b** (34%), **14c** (48%). The cross metathesis of **9** with **12c** was also run under catalysis of Grubbs first generation catalyst[22] for comparison, and expected product **14c** was isolated in a marginally lower yield of 43%. Finally, the series of reactions of allyl-γ-cyclodextrin **10** with **12a**–**c** were carried out as well, giving rise to the corresponding perfluoroalkylated γ-cyclodextrins: **15a** (24%), **15b** (29%), and **15c** (38%). To assess the scope of the reaction with respect to cyclodextrins allylated in various positions, the reaction was also conducted between 2^{I}-*O*-allyl-per-*O*-acetyl-β-cyclodextrin **11** and **12c**. As expected, the reaction proceeded uneventfully to furnish desired product **16c** in 50% yield after isolation. Compounds **13**–**16** were all prepared with a *cis*/*trans* ration of 1:5 (^{1}H NMR spectroscopy). Attempts to separate these isomers were unsuccessful.



Scheme 3. Cross metathesis of allylcyclodextrins **8**–**11** with perfluoroalkylpropenes **12**.

Fluorinated derivatives of cyclodextrins with the longest alkyl chain – n-C_6F_{13} – **13c**, **14c**, **15c**, and **16c**, which can be expected to form the most stable aggregates, were chosen for deacetylation and testing of amphiphilic properties. Zemplen deacetylation (MeONa/MeOH) of these compounds furnished deacetylated derivatives **17c**, **18c**, **19c**, and **20c** in 94–97% yield (Scheme 4).

There are only a few examples of measurements of aggregates of amphiphilic cyclodextrins bearing only one hydrophobic anchor. Silva et al.[23] prepared colloidal particles with a size of 49 nm and Zhang et al.[24] prepared vesicles



Scheme 4. Deprotection of **13c**, **14c**, **15c**, and **16c**.

with hydrodynamic radii of 107 nm in similar concentrations. Other more highly substituted amphiphilic cyclodextrin derivatives form aggregates in water with sizes varying from several tens to several hundreds of nanometers.[7,25]

Dynamic light scattering measurements of colloidal solutions of fluorinated cyclodextrins **17c**–**20c** were carried out in water after 15 min and 7 d to study their tendency to form aggregates (Table 1). A concentration of 2 mg/1 mL was used for **18c** and **20c**. For **17c** and **19c**, precipitation was observed at the previously mentioned concentrations; thus, the measurements were carried out at a concentration of 0.2 mg/1 mL. Generally, the measurements revealed that after 15 min compounds **17c**–**20c** formed two types of nanoparticles with hydrodynamic radii ranges of 50–127 and 360–1000 nm. After 7 d, the particle size increased to higher values with maxima observed in the ranges of 70–470 and 610–3600 nm (Table 1). Such a trend was observed for compounds **17c**, **18c**, and **20c** (Figures 1, 2, and 3). Interestingly for compound **19c**, this phenomenon was not observed, only broadening of the particle size distribution was observed (Figure 4).

Table 1. Radii of the colloid particles of **17c**–**20c**.

Entry	Compound	Radii [nm] of particles after 15 min	7 d
1	**17c**	50	70
		360	950
2	**18c**	127	470
		1000	3700
3	**19c**	84	81
		600	610
4	**20c**	94	117
		480	1800

Conclusions

In conclusion we have shown that cross metathesis of allylated cyclodextrins with perfluoroalkylpropenes constitutes a simple and reliable synthetic tool for the preparation of perfluoroalkylated cyclodextrins. Supramolecular properties were shown on chosen representatives of cyclodextrins bearing a fluorinated anchor. The size of the aggregates in water ranged from 49 to 3700 nm.

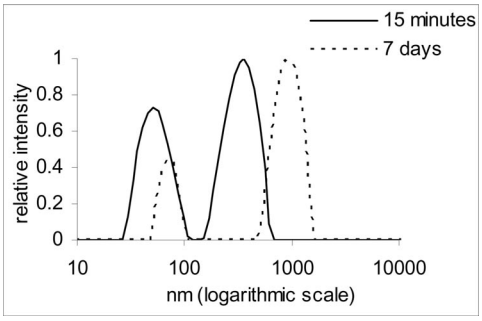


Figure 1. Radii of the colloid particles of **17c** in water.

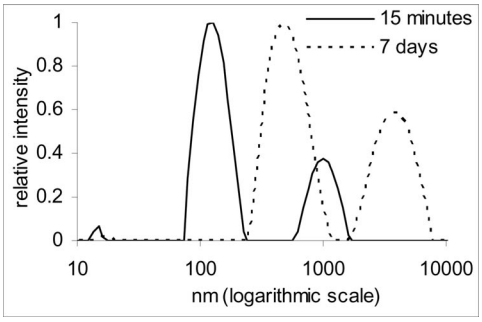


Figure 2. Radii of the colloid particles of **18c** in water.

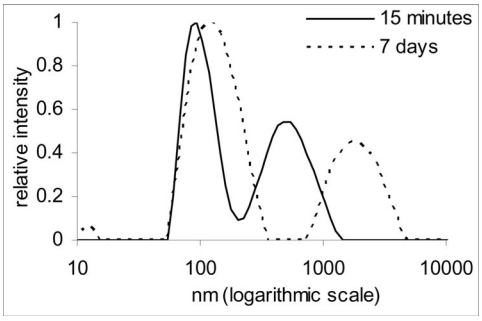


Figure 3. Radii of the colloid particles of **20c** in water.

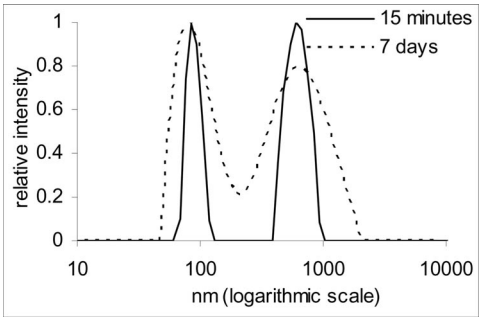


Figure 4. Radii of the colloid particles of **19c** in water.

Experimental Section

General Procedure for Cross Metathesis between Peracetylated Allylcyclodextrins and (Perfluoroalkyl)propenes: The Hoveyda–Grubbs second generation catalyst (0.01 mmol) was added under

an atmosphere of argon to a mixture of an allylcyclodextrin (0.1 mmol) and a (perfluoroalkyl)propene (0.5 mmol) in dichloromethane (20 mL). The resulting solution was stirred at 42 °C overnight. Removal of the solvent in vacuo gave a brown residue that was purified by flash chromatography on silica gel ($CHCl_3$/MeOH, 100:1) and by column chromatography (MeOH/H_2O, 5:1) on C_{18} reverse-phase silica.

Per-*O*-acetyl-6^I-*O*-(5,5,6,6,7,7,7-heptafluorohept-2-en-1-yl)-α-cyclodextrin (13a): The reaction was run with compounds **8** (100 mg, 0.058 mmol) and **12a** (61 mg, 0.29 mmol). Workup afforded, after column chromatography, the title compound as a white powder (35 mg, 32%). M.p. 119–121 °C. $[\alpha]_D^{20}$ = +87 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.82 (dt, J = 15.7, 5.5 Hz, 1 H, 2′-H), 5.73–5.38 (m, 7 H, 6×3-H, 1×3′-H), 5.12–5.02 (m, 4 H, 4×1-H), 4.98 (d, J = 3.3 Hz, 2 H, 2×1-H), 4.83–4.68 (m, 6 H, 6×2-H), 4.53–3.60 (m, 26 H, 2×1′-H, 6×4-H, 6×5-H, 12×6-H), 2.84 (td, $J_{H,F}$ = 18.7 Hz, $J_{H,H}$ = 6.7 Hz, 2 H, 2×4′-H), 2.20–1.97 (m, 51 H, 17×CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.77–169.06 (17×C=O), 134.16 (*trans*-C-2′), 132.89 (*cis*-C-2′), 120.01 (t, $J_{C,F}$ = 4.1 Hz, C-3′), 97.11 (C-1), 96.72 (C-1), 96.53 (C-1), 96.48 (C-1), 96.32 (C-1), 96.15 (C-1), 77.76–69.01 (6×C-2, 6×C-3, 6×C-4, 6×C-5), 71.13 (C-1′), 68.33 (C-6^I), 63.16–63.04 (5×C-6), 34.10 (t, $J_{C,F}$ = 22.8 Hz, C-4′), 20.89–20.62 (17×CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –80.96 (t, J = 9.6 Hz, 3 F, 3×F-7′), –(114.25–114.62) (m, 2 F, 2×F-6′), –(127.66–127.71) (m, 2 F, 2×*cis*-F-5′), –(127.78–127.84) (m, 2 F, 2×*trans*-F-5′) ppm. IR (drift KBr): $\tilde{\nu}$ = 1745, 1370, 1238, 1043 cm^{-1}. MS (ESI): *m*/*z* = 1931.5 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-[5,6,6,6-tetrafluoro-5-(trifluoromethyl)hex-2-en-1-yl]-α-cyclodextrin (13b): The reaction was run with compounds **8** (100 mg, 0.058 mmol) and **12b** (61 mg, 0.29 mmol). Workup afforded, after column chromatography, the title compound as a white powder (41 mg, 37%). M.p. 122–124 °C. $[\alpha]_D^{20}$ = +89 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.79 (dt, J = 15.4, 5.4 Hz, 1 H, 2′-H), 5.72–5.37 (m, 7 H, 6×3-H, 1×3′-H), 5.11–5.02 (m, 3 H, 3×1-H), 5.04 (d, J = 3.6 Hz, 1 H, 1-H), 4.98 (d, J = 3.6 Hz, 1 H, 1-H), 4.96 (d, J = 3.4 Hz, 1 H, 1-H), 4.82–4.67 (m, 6 H, 6×2-H), 4.54–3.55 (m, 26 H, 2×1′-H, 6×4-H, 6×5-H, 12×6-H), 2.85 (dd, $J_{H,F}$ = 19.8 Hz, $J_{H,H}$ = 6.9 Hz, 2 H, 2×4′-H), 2.16–1.98 (m, 51 H, 17×CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.73–169.06 (17×C=O), 133.49 (*trans*-C-2′), 132.03 (*cis*-C-2′), 120.95 (d, $J_{C,F}$ = 5.7 Hz, C-3′), 97.02 (C-1), 96.68 (C-1), 96.47 (C-1), 96.44 (C-1), 96.25 (C-1), 96.09 (C-1), 77.75–69.01 (6×C-2, 6×C-3, 6×C-4, 6×C-5), 71.01 (C-1′), 68.32 (C-6^I), 63.12–62.99 (5×C-6), 31.96 (d, $J_{C,F}$ = 20.4 Hz, C-4′), 20.87–20.62 (17×CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –76.01 (d, J = 7.0 Hz, 6 F, 2×*trans*-CF_3), –76.19 (d, J_F = 6.9 Hz, 6 F, 2×*cis*-CF_3), –(182.22–182.50) (m, 1 F, *trans*-F-5′), –(182.87–183.10) (m, 1 F, *cis*-F-5′) ppm. IR (drift KBr): $\tilde{\nu}$ = 1747, 1372, 1240, 1045 cm^{-1}. MS (ESI): *m*/*z* = 1931.6 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-tridecafluorodec-2-en-1-yl)-α-cyclodextrin (13c): The reaction was run with compounds **8** (92 mg, 0.053 mmol) and **12c** (96 mg, 0.27 mmol). Workup afforded, after column chromatography, the title compound as a white powder (47 mg, 43%). M.p. 116–118 °C. $[\alpha]_D^{20}$ = +80 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.82 (dt, J = 15.5, 5.6 Hz, 1 H, 2′-H), 5.73–5.61 (m, 1 H, 3′-H), 5.60 (dd, J = 10.6, 8.8 Hz, 1 H, 3-H), 5.57 (dd, J = 10.4, 8.3 Hz, 1 H, 3-H), 5.56 (dd, J = 10.5, 8.5 Hz, 1 H, 3-H), 5.51 (dd, J = 9.8, 7.8 Hz, 1 H, 3-H), 5.45 (dd, J = 10.2, 8.6 Hz, 1 H, 3-H), 5.44 (dd, J = 10.3, 8.4 Hz, 1 H, 3-H), 5.11–5.02 (m, 4 H, 4×1-H), 4.98 (d, J = 3.4 Hz, 2 H, 2×1-H), 4.82–4.67 (m, 6 H, 6×2-H), 4.51–3.59 (m, 26 H, 2×1′-H, 6×4-H, 6×5-H, 12×6-H), 2.85 (td, $J_{H,F}$ = 18.5 Hz, $J_{H,H}$ = 6.7 Hz, 2 H, 2×4′-H), 2.22–1.91 (m, 51 H, 17×CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.76–169.02 (17×C=O), 134.21 (*trans*-C-2′), 132.98 (*cis*-C-2′), 120.02 (m, C-3′), 97.13 (C-1), 96.73 (C-1), 96.54 (C-1), 96.48 (C-1), 96.34 (C-1), 96.16 (C-1), 77.78–69.00 (6×C-2, 6×C-3, 6×C-4, 6×C-5), 71.16 (C-1′), 68.34 (C-6^I), 63.17–63.05 (5×C-6), 34.31 (t, $J_{C,F}$ = 22.6 Hz, C-4′), 20.92–20.58 (17×CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –80.78 (tt, J = 9.9, 2.5 Hz, 3×F-10′), –(112.89–113.40) (m, 2 F), –(121.73–122.09) (m, 2 F), –(122.67–123.02) (m, 2 F), –(123.02–123.30) (m, 2 F), –(125.97–126.24) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 1748, 1372, 1241, 1043 cm^{-1}. MS (ESI): *m*/*z* = 2081.5 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-(5,5,6,6,7,7,7-heptafluorohept-2-en-1-yl)-β-cyclodextrin (14a): The reaction was run with compounds **9** (100 mg, 0.050 mmol) and **12a** (52 mg, 0.25 mmol). Workup afforded, after column chromatography, the title compound as a white powder (47 mg, 43%). M.p. 117–119 °C. $[\alpha]_D^{20}$ = +103 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.81 (dt, J = 15.5, 5.5 Hz, 1 H, 2′-H), 5.72–5.60 (m, 1 H, 3′-H), 5.40–5.17 (m, 7 H, 7×3-H), 5.13 (d, J = 3.9 Hz, 1 H, 1-H), 5.10 (d, J = 4.3 Hz, 1 H, 1-H), 5.08 (d, J = 3.9 Hz, 1 H, 1-H), 5.07–5.03 (m, 3 H, 3×1-H), 5.02 (d, J = 3.9 Hz, 1 H, 1-H), 4.85–4.67 (m, 7 H, 7×2-H), 4.60–3.55 (m, 30 H, 2×1′-H, 7×4-H, 7×5-H, 14×6-H), 2.83 (td, $J_{H,F}$ = 18.6 Hz, $J_{H,H}$ = 6.5 Hz, 2 H, 2×4′-H), 2.10–1.97 (m, 60 H, 20×CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.90–169.25 (20×C=O), 134.04 (*trans*-C-2′), 132.78 (*cis*-C-2′), 119.93 (t, $J_{C,F}$ = 4.3 Hz, C-3′), 97.11 (C-1), 96.93 (C-1), 96.83 (C-1), 96.75 (C-1), 96.46 (C-1), 96.42 (C-1), 96.33 (C-1), 77.00–69.24 (7×C-2, 7×C-3, 7×C-4, 7×C-5), 71.06 (C-1′), 67.77 (C-6^I), 62.68–62.37 (6×C-6), 34.10 (t, $J_{C,F}$ = 22.6 Hz, C-4′), 20.86–20.60 (20×CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –80.92 (t, J = 9.8 Hz, 3 F, 3×*cis*-F-7′), –80.97 (t, J = 9.6 Hz, 3 F, 3×*trans*-F-7′), –(114.37–114.63) (m, 2 F, 2×F-6′), –(127.65–127.71) (m, 2 F, 2×*cis*-F-5′), –(127.79–127.82) (m, 2 F, 2×*trans*-F-5′) ppm. IR (drift KBr): $\tilde{\nu}$ = 1749, 1371, 1236, 1048 cm^{-1}. MS (ESI): *m*/*z* = 2219.3 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-[5,6,6,6-tetrafluoro-5-(trifluoromethyl)hex-2-en-1-yl]-β-cyclodextrin (14b): The reaction was run with compounds **9** (100 mg, 0.050 mmol) and **12b** (52 mg, 0.25 mmol). Workup afforded, after column chromatography, the title compound as a white powder (37 mg, 34%). M.p. 118–120 °C. $[\alpha]_D^{20}$ = +102 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.79 (dt, J = 15.5, 5.4 Hz, 1 H, 2′-H), 5.71–5.58 (m, 1 H, 3′-H), 5.41–5.17 (m, 7 H, 7×3-H), 5.13 (d, J = 3.9 Hz, 1 H, 1-H), 5.10 (d, J = 4.3 Hz, 1 H, 1-H), 5.08 (d, J = 3.9 Hz, 1 H, 1-H), 5.07–5.00 (m, 4 H, 4×1-H), 4.86–4.67 (m, 7 H, 7×2-H), 4.61–3.54 (m, 30 H, 2×1′-H, 7×4-H, 7×5-H, 14×6-H), 2.84 (dd, $J_{H,F}$ = 19.9 Hz, $J_{H,H}$ = 6.9 Hz, 2 H, 2×4′-H), 2.10–1.97 (m, 60 H, 20×CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.89–169.24 (20×C=O), 133.42 (*trans*-C-2′), 131.98 (*cis*-C-2′), 120.93 (d, $J_{C,F}$ = 5.7 Hz, C-3′), 97.11 (C-1), 96.93 (C-1), 96.82 (C-1), 96.75 (C-1), 96.45 (C-1), 96.40 (C-1), 96.36 (C-1), 77.03–69.18 (7×C-2, 7×C-3, 7×C-4, 7×C-5), 70.99 (C-1′), 67.78 (C-6^I), 62.68–62.35 (6×C-6), 32.00 (d, $J_{C,F}$ = 20.7 Hz, C-4′), 20.87–20.60 (20×CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –76.41 (d, J = 7.0 Hz, 6 F, 2×*trans*-CF_3), –76.58 (d, J = 7.0 Hz, 6 F, 2×*cis*-CF_3), –(182.61–182.87) (m, 1 F, *trans*-F-5′), –(183.21–183.42) (m, 1 F, *cis*-F-5′) ppm. IR (drift KBr): $\tilde{\nu}$ = 1749, 1371, 1237, 1047 cm^{-1}. MS (ESI): *m*/*z* = 2219.5 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-tridecafluorodec-2-en-1-yl)-β-cyclodextrin (14c): The reaction was run with compounds **9** (300 mg, 0.15 mmol) and **12c** (268 mg, 0.74 mmol). Workup afforded, after column chromatography, the title compound as a white powder (168 mg, 48%). (This product was also prepared by

using Grubbs first generation catalyst in 42% yield.) M.p. 115–117 °C. $[\alpha]_D^{20}$ = +100 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.81 (dt, J = 15.8, 5.4 Hz, 1 H, 2′-H), 5.72–5.60 (m, 1 H, 3′-H), 5.41–5.18 (m, 7 H, 7 × 3-H), 5.14 (d, J = 3.9 Hz, 1 H, 1-H), 5.11–5.02 (m, 6 H, 6 × 1-H), 4.86–4.67 (m, 7 H, 7 × 2-H), 4.61–3.56 (m, 30 H, 2 × 1′-H, 7 × 4-H, 7 × 5-H, 14 × 6-H), 2.85 (td, $J_{H,F}$ = 18.9 Hz, $J_{H,H}$ = 6.7 Hz, 2 H, 2 × 4′-H), 2.10–1.98 (m, 60 H, 20 × CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.90–169.28 (20 × C=O), 134.11 (*trans*-C-2′), 132.89 (*cis*-C-2′), 119.97 (t, $J_{C,F}$ = 4.1 Hz, C-3′), 97.14 (C-1), 96.94 (C-1), 96.86 (C-1), 96.77 (C-1), 96.48 (C-1), 96.48 (C-1), 96.34 (C-1), 77.22–69.22 (7 × C-2, 7 × C-3, 7 × C-4, 7 × C-5), 71.11 (C-1′), 67.82 (C-6^I), 62.71–62.39 (6 × C-6), 34.35 (t, $J_{C,F}$ = 22.6 Hz, C-4′), 20.86–20.62 (20 × CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –80.79 (tt, J = 9.9, 2.4 Hz, 3 F, 3 × F-10′), –(112.91–113.36) (m, 2 F), –(121.77–122.10) (m, 2 F), –(122.71–123.02) (m, 2 F), –(123.02–123.26) (m, 2 F), –(126.01–126.22) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 1750, 1370, 1241, 1052 cm^{-1}. MS (ESI): m/z = 2370.2 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-(5,5,6,6,7,7,7-heptafluorohept-2-en-1-yl)-γ-cyclodextrin (15a): The reaction was run with compounds **10** (100 mg, 0.043 mmol) and **12a** (46 mg, 0.22 mmol). Workup afforded, after column chromatography, the title compound as a white powder (26 mg, 24%). M.p. 121–123 °C. $[\alpha]_D^{20}$ = +109 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.87–5.77 (m, 1 H, 2′-H), 5.72–5.61 (m, 1 H, 3′-H), 5.42–5.23 (m, 8 H, 8 × 3-H), 5.20 (d, J = 3.8 Hz, 1 H, 1-H), 5.16 (d, J = 3.8 Hz, 1 H, 1-H), 5.15–5.05 (m, 6 H, 6 × 1-H), 4.77–4.65 (m, 8 H, 8 × 2-H), 4.61–3.55 (m, 34 H, 2 × 1′-H, 8 × 4-H, 8 × 5-H, 16 × 6-H), 2.84 (td, $J_{H,F}$ = 18.7 Hz, $J_{H,H}$ = 6.9 Hz, 2 H, 2 × 4′-H), 2.13–2.00 (m, 69 H, 23 × CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.74–169.25 (23 × C=O), 134.02 (*trans*-C-2′), 132.77 (*cis*-C-2′), 120.06 (t, $J_{C,F}$ = 4.5 Hz, C-3′), 96.47 (C-1), 96.40 (C-1), 96.29 (C-1), 96.27–96.04 (5 × C-1), 77.20–69.55 (8 × C-2, 8 × C-3, 8 × C-4, 8 × C-5), 71.04 (C-1′), 67.79 (C-6^I), 62.70–62.26 (7 × C-6), 34.10 (t, $J_{C,F}$ = 22.5 Hz, C-4′), 20.89–20.62 (23 × CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –80.52 (t, J = 9.9 Hz, 3 F, 3 × *cis*-F-7′), –80.57 (t, J = 9.9 Hz, 3 F, 3 × *trans*-F-7′), –(113.58–114.42) (m, 2 F, 2 × F-6′), –(127.20–127.27) (m, 2 F, 2 × *cis*-F-5′), –(127.34–127.48) (m, 2 F, 2 × *trans*-F-5′) ppm. IR (drift KBr): $\tilde{\nu}$ = 1750, 1370, 1239, 1043 cm^{-1}. MS (ESI): m/z = 2508.1 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-[5,6,6,6-tetrafluoro-5-(trifluoromethyl)hex-2-en-1-yl]-γ-cyclodextrin (15b): The reaction was run with compounds **10** (100 mg, 0.043 mmol) and **12b** (46 mg, 0.22 mmol). Workup afforded, after column chromatography, the title compound as a white powder (31 mg, 29%). M.p. 125–127 °C. $[\alpha]_D^{20}$ = +112 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.81 (dt, J = 15.6, 5.6 Hz, 1 H, 2′-H), 5.73–5.60 (m, 1 H, 3′-H), 5.43–5.25 (m, 8 H, 8 × 3-H), 5.21 (d, J = 3.8 Hz, 1 H, 1-H), 5.18 (d, J = 3.9 Hz, 1 H, 1-H), 5.17–5.06 (m, 6 H, 6 × 1-H), 4.79–4.67 (m, 8 H, 8 × 2-H), 4.63–3.54 (m, 34 H, 2 × 1′-H, 8 × 4-H, 8 × 5-H, 16 × 6-H), 2.87 (dd, $J_{H,F}$ = 19.7 Hz, $J_{H,H}$ = 7.1 Hz, 2 H, 2 × 4′-H), 2.15–2.01 (m, 69 H, 23 × CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.82–169.20 (23 × C=O), 133.41 (C-2′), 121.07 (d, $J_{C,F}$ = 6.3 Hz, C-3′), 96.46 (C-1), 96.39 (C-1), 96.34 (C-1), 96.30–96.02 (5 × C-1), 76.56–69.45 (8 × C-2, 8 × C-3, 8 × C-4, 8 × C-5), 70.98 (C-1′), 67.81 (C-6^I), 62.72–62.26 (7 × C-6), 32.01 (d, $J_{C,F}$ = 21.9 Hz, C-4′), 20.90–20.62 (20 × CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –76.01 (d, J = 6.6 Hz, 6 F, 2 × *trans*-CF_3), –76.17 (d, J = 7.4 Hz, 6 F, 2 × *cis*-CF_3), –(182.20–182.51) (m, 1 F, *trans*-F-5′), –(182.76–183.00) (m, 1 F, *cis*-F-5′) ppm. IR (drift KBr): $\tilde{\nu}$ = 1750, 1371, 1238, 1045 cm^{-1}. MS (ESI): m/z = 2508.0 [M + Na]$^+$.

Per-*O*-acetyl-6^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-tridecafluorodec-2-en-1-yl)-γ-cyclodextrin (15c): The reaction was run with compounds **10** (100 mg, 0.043 mmol) and **12c** (78 mg, 0.22 mmol). Workup afforded, after column chromatography, the title compound as a white powder (43 mg, 38%). M.p. 124–126 °C. $[\alpha]_D^{20}$ = +106 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.82 (dt, J = 15.4, 5.6 Hz, 1 H, 2′-H), 5.73–5.61 (m, 1 H, 3′-H), 5.43–5.24 (m, 8 H, 8 × 3-H), 5.20 (d, J = 3.9 Hz, 1 H, 1-H), 5.16 (d, J = 4.0 Hz, 1 H, 1-H), 5.14–5.04 (m, 6 H, 6 × 1-H), 4.77–4.64 (m, 8 H, 8 × 2-H), 4.61–3.55 (m, 34 H, 2 × 1′-H, 8 × 4-H, 8 × 5-H, 16 × 6-H), 2.85 (td, $J_{H,F}$ = 18.6 Hz, $J_{H,H}$ = 6.5 Hz, 2 H, 2 × 4′-H), 2.13–1.99 (m, 69 H, 23 × CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.84–169.15 (23 × C=O), 134.05 (*trans*-C-2′), 132.86 (*cis*-C-2′), 120.19–119.99 (m, C-3′), 96.46 (C-1), 96.39 (C-1), 96.32–95.98 (6 × C-1), 77.20–69.47 (8 × C-2, 8 × C-3, 8 × C-4, 8 × C-5), 71.07 (C-1′), 67.81 (C-6^I), 62.70–62.20 (7 × C-6), 34.32 (t, $J_{C,F}$ = 22.3 Hz, C-4′), 20.90–20.60 (20 × CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –80.78 (tt, J = 10.1, 2.7 Hz, 3 F, 3 × F-10′), –(113.08–113.35) (m, 2 F), –(121.21–122.30) (m, 2 F), –(122.30–123.03) (m, 2 F), –(123.03–123.49) (m, 2 F), –(125.79–126.45) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 1751, 1371, 1238, 1046 cm^{-1}. MS (ESI): m/z = 2657.9 [M + Na]$^+$.

Per-*O*-acetyl-2^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-tridecafluorodec-2-en-1-yl)-β-cyclodextrin (16c): The reaction was run with compounds **11** (75 mg, 0.037 mmol) and **12c** (67 mg, 0.19 mmol). Workup afforded, after column chromatography, the title compound as a white powder (44 mg, 50%). M.p. 115–117 °C. $[\alpha]_D^{20}$ = +95 ($CHCl_3$). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 5.74 (dt, J = 15.4, 4.8 Hz, 1 H, 2′-H), 5.64 (dt, J = 15.7, 6.5 Hz, 1 H, 3′-H), 5.35–5.15 (m, 7 H, 7 × 3-H), 5.11–5.02 (m, 5 H, 5 × 1-H), 5.00 (d, J = 3.9 Hz, 1 H, 1-H), 4.91 (d, J = 3.3 Hz, 1 H, 1^I-H), 4.86–4.70 (m, 6 H, 6 × 2-H), 4.61–3.53 (m, 30 H, 2 × 1′-H, 7 × 4-H, 7 × 5-H, 14 × 6-H), 3.30 (dd, J = 9.8, 3.4 Hz, 1 H, 2^I-H), 2.85 (td, $J_{H,F}$ = 18.4 Hz, $J_{H,H}$ = 6.1 Hz, 2 H, 2 × 4′-H), 2.10–1.97 (m, 60 H, 20 × CH_3) ppm. ^{13}C NMR (101 MHz, $CDCl_3$): δ = 170.85–169.09 (20 × C=O), 134.14 (C-2′), 119.88 (C-3′), 98.10 (C-1), 97.08 (C-1), 97.05 (C-1), 96.82 (C-1), 96.60 (C-1), 96.56 (C-1), 96.49 (C-1), 78.13–69.46 (7 × C-2, 7 × C-3, 7 × C-4, 7 × C-5), 70.58 (C-1′), 62.93–62.26 (7 × C-6), 34.32 (t, $J_{C,F}$ = 22.4 Hz, C-4′), 20.85–20.60 (20 × CH_3) ppm. ^{19}F NMR (282 MHz, $CDCl_3$): δ = –81.18 (tt, J = 9.7, 2.2 Hz, 3 F, 3 × F-10′), –(113.39–113.65) (m, 2 F), –(122.20–122.49) (m, 2 F), –(123.17–123.58) (m, 4 F), –(126.42–126.60) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 1748, 1372, 1239, 1048 cm^{-1}. MS (ESI): m/z = 2369.3 [M + Na]$^+$.

General Procedure for Zemplen Deacetylation of *O*-Perfluoralkylated Cyclodextrins: A solution of MeONa in MeOH (0.1 M, 1 mL, 0.1 mmol) was added to **17c**–**20c** (0.025 mmol) under an argon atmosphere. The reaction mixture was stirred for 1 h, quenched by the addition of water (1 mL), and passed through DOWEX 50Wx2 in H^+ form. Recrystallization from 50% MeOH in water afforded the desired product.

6^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-Tridecafluorodec-2-en-1-yl)-α-cyclodextrin (17c): The reaction was run with compound **13c** (34 mg, 0.017 mmol). Workup afforded the title compound as a white powder (22 mg, 97%). M.p. 260 °C (decomp.) $[\alpha]_D^{20}$ = +73 (CH_3OH). ^{1}H NMR (300 MHz, CD_3OD): δ = 5.95 (dt, J = 15.5, 5.5 Hz, 1 H, 2′-H), 5.74 (dt, J = 15.1, 7.2 Hz, 1 H, 3′-H), 4.97–4.89 (m, 6 H, 6 × 1-H), 4.09 (d, J = 5.9 Hz, 1 H, 1′-H), 3.99–3.42 (m, 36 H, 6 × 2-H, 6 × 3-H, 6 × 4-H, 6 × 5-H, 12 × 6-H), 2.99 (td, $J_{H,F}$ = 18.8 Hz, $J_{H,H}$ = 7.1 Hz, 2 H, 2 × 4′-H) ppm. ^{13}C NMR (151 MHz, CD_3OD): δ = 136.32 (C-2′), 120.25 (C-3′), 103.97–103.50 (6 × C-1), 83.50–61.49 (6 × C-2, 6 × C-3, 6 × C-4, 6 × C-5,

6 × C-6, C-1′), 35.17 (t, $J_{C,F}$ = 22.1 Hz, C-4′) ppm. ^{19}F NMR (282 MHz, CD_3OD): δ = –(82.34–82.36) (m, 3 F, 3 × F-10′), –(113.95–114.40) (m, 2 F), –(122.75–123.08) (m, 2 F), –(123.72–124.24) (m, 4 F), –(127.18–127.45) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 3300, 1152, 1080, 1033 cm^{-1}. MS (ESI): *m*/*z* = 1367.4 [M + Na]$^+$.

6^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-Tridecafluorodec-2-en-1-yl)-β-cyclodextrin (18c): The reaction was run with compound **14c** (83 mg, 0.035 mmol). Workup afforded the title compound as a white powder (50 mg, 94%). M.p. 260 °C (decomp.) $[\alpha]_D^{20}$ = +73 (CH_3OH). ^{1}H NMR (300 MHz, CD_3OD): δ = 5.96 (dt, *J* = 15.8, 5.4 Hz, 1 H, 2′-H), 5.81–5.69 (m, 1 H, 3′-H), 5.00–4.90 (m, 7 H, 7 × 1-H), 4.15 (dd, *J* = 13.6, 5.0 Hz, 1 H, 1a′-H), 4.06 (dd, *J* = 13.3, 5.6 Hz, 1 H, 1b′-H), 3.95–3.43 (m, 42 H, 7 × 2-H, 7 × 3-H, 7 × 4-H, 7 × 5-H, 14 × 6-H), 2.85 (td, $J_{H,F}$ = 18.4 Hz, $J_{H,H}$ = 6.5 Hz, 2 H, 2 × 4′-H) ppm. ^{13}C NMR (101 MHz, CD_3OD): δ = 136.64 (*trans*-C-2′), 134.23 (*cis*-C-2′), 120.82–120.13 (m, C-3′), 104.37–103.99 (7 × C-1), 84.00–61.42 (7 × C-2, 7 × C-3, 7 × C-4, 7 × C-5, 7 × C-6, C-1′), 35.57 (t, $J_{C,F}$ = 23.0 Hz, C-4′) ppm. ^{19}F NMR (282 MHz, CD_3OD): δ = –(81.61–81.72) (m, 3 F, 3 × *cis*-F-10′), –(82.06–82.18) (m, 3 F, 3 × *trans*-F-10′), –(113.12–113.48) (m, 2 F), –(122.32–122.77) (m, 2 F), –(123.14–123.61) (m, 4 F), –(126.90–127.09) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 3304, 1157, 1082, 1032 cm^{-1}. MS (ESI): *m*/*z* = 1529.5 [M + Na]$^+$.

6^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-Tridecafluorodec-2-en-1-yl)-γ-cyclodextrin (19c): The reaction was run with compound **15c** (27 mg, 0.010 mmol). Workup afforded the title compound as a white powder (16 mg, 96%). M.p. 260 °C (decomp.) $[\alpha]_D^{20}$ = +75 (CH_3OH). ^{1}H NMR (300 MHz, CD_3OD): δ = 5.95 (dt, *J* = 15.1, 5.3 Hz, 1 H, 2′-H), 5.75 (dt, *J* = 15.2, 7.3 Hz, 1 H, 3′-H), 5.06–4.95 (m, 8 H, 8 × 1-H), 4.10 (d, *J* = 5.6 Hz, 1 H, 1′-H), 3.92–3.41 (m, 48 H, 8 × 2-H, 8 × 3-H, 8 × 4-H, 8 × 5-H, 16 × 6-H), 3.00 (td, $J_{H,F}$ = 18.7 Hz, $J_{H,H}$ = 6.8 Hz, 2 H, 2 × 4′-H) ppm. ^{13}C NMR (151 MHz, CD_3OD): δ = 136.31 (*trans*-C-2′), 134.63 (*cis*-C-2′), 120.23 (C-3′), 104.12–103.79 (8 × C-1), 83.08–61.73 (8 × C-2, 8 × C-3, 8 × C-4, 8 × C-5, 8 × C-6, C-1′), 35.21 (t, $J_{C,F}$ = 22.3 Hz, C-4′) ppm. ^{19}F NMR (282 MHz, CD_3OD): δ = –83.38 (tt, *J* = 9.9, 2.6 Hz, 3 F, 3 × F-10′), –(114.06–114.33) (m, 2 F), –(122.73–123.06) (m, 2 F), –(123.75–124.18) (m, 4 F), –(127.12–127.40) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 3306, 1156, 1080, 1031 cm^{-1}. MS (ESI): *m*/*z* = 1691.6 [M + Na]$^+$.

2^I-*O*-(5,5,6,6,7,7,8,8,9,9,10,10,10-Tridecafluorodec-2-en-1-yl)-β-cyclodextrin (20c): The reaction was run with compound **16c** (28 mg, 0.012 mmol). Workup afforded the title compound as a white powder (17 mg, 95%). M.p. 260 °C (decomp.) $[\alpha]_D^{20}$ = +72 (CH_3OH). ^{1}H NMR (300 MHz, CD_3OD): δ = 5.98 (dt, *J* = 15.5, 6.3 Hz, 1 H, 2′-H), 5.79 (dt, *J* = 15.0, 7.1 Hz, 1 H, 3′-H), 5.04 (d, *J* = 3.4 Hz, 1 H, 1^I-H), 4.96 (d, *J* = 2.9 Hz, 6 H, 6 × 1-H), 4.38 (dd, *J* = 12.6, 5.9 Hz, 1 H, 1a′-H), 4.28 (dd, *J* = 12.2, 6.4 Hz, 1 H, 1b′-H), 3.98 (t, *J* = 9.1 Hz, 1 H, 3^I-H), 3.92–3.43 (m, 40 H, 6 × 2-H, 6 × 3-H, 7 × 4-H, 7 × 5-H, 14 × 6-H), 3.40 (dd, *J* = 9.7, 3.6 Hz, 1 H, 2^I-H), 3.01 (td, $J_{H,F}$ = 18.9 Hz, $J_{H,H}$ = 6.3 Hz, 2 H, 2 × 4′-H) ppm. ^{13}C NMR (151 MHz, CD_3OD): δ = 135.51 (C-2′), 122.48 (C-3′), 104.06–102.28 (7 × C-1), 84.08–61.73 (7 × C-2, 7 × C-3, 7 × C-4, 7 × C-5, 7 × C-6, C-1′), 35.22 (t, $J_{C,F}$ = 22.7 Hz, C-4′) ppm. ^{19}F NMR (282 MHz, CD_3OD): δ = –(82.28–82.40) (m, 3 F, 3 × F-10′),–(113.93–114.25) (m, 2 F), –(122.61–122.96) (m, 2 F), –(123.62–124.19) (m, 4 F), –(127.09–127.39) (m, 2 F) ppm. IR (drift KBr): $\tilde{\nu}$ = 3307, 1155, 1080, 1032 cm^{-1}. MS (ESI): *m*/*z* = 1529.5 [M + Na]$^+$.

Light Scattering Measurements: A suspension of fluorinated cyclodextrin **17c**–**20c** (2 mg for **18c**, **20c** or 0.2 mg for **17c** and **19c** derivatives) in water (1 mL) was ultrasonicated for 5 min (**17c** and **19c** derivatives were measured in lower concentrations due to precipitation in higher concentrations). One light scattering measurement of derivatives was carried out after 15 min. The suspension was than stored 7 d at room temperature and second measurement was carried out.

Supporting Information (see footnote on the first page of this article): General information for the Experimental Section, preparation of allylated cyclodextrins **4**–**11**, and copies of the spectra for all prepared substances.

Acknowledgments

This work was supported by the Ministry of Education, Youth, and Sports (project No. MSM0021620857) and the Academy of Sciences of the Czech Republic (project No. KAN 200200651).

[1] a) M. P. Krafft, *Adv. Drug Delivery Rev.* **2001**, *47*, 209–228; b) J. Riess, *Curr. Opin. Colloid Interface Sci.* **2009**, *14*, 294–304.
[2] C. Gadras, C. Santaella, P. Vierling, *J. Control. Release* **1999**, *57*, 29–34.
[3] M. Schmutz, B. Michels, P. Marie, M. P. Krafft, *Langmuir* **2003**, *19*, 4889–4894.
[4] D. Duchêne, G. Ponchel, D. Wouessidjewe, *Adv. Drug Delivery Rev.* **1999**, *36*, 29–40.
[5] M. Roux, B. Perly, F. Djedaïni-Pilard, *Eur. Biophys. J.* **2007**, *36*, 861–867.
[6] F. Sallas, R. Darcy, *Eur. J. Org. Chem.* **2008**, 957–969.
[7] C. E. Granger, C. P. Félix, H. P. Parrot-Lopez, B. R. Langlois, *Tetrahedron Lett.* **2000**, *41*, 9257–9260.
[8] M. M. Becker, B. J. Ravoo, *Chem. Commun.* **2010**, *46*, 4369–4371.
[9] a) S. Peroche, H. Parrot-Lopez, *Tetrahedron Lett.* **2003**, *44*, 241–245; b) S. Peroche, G. Degobert, J.-L. Putaux, M.-G. Blanchin, H. Fessi, H. Parrot-Lopez, *Eur. J. Pharm. Biopharm.* **2005**, *60*, 123–131; c) B. B. Ghera, F. Perret, A. Baudouin, A. W. Coleman, H. Parrot-Lopez, *New J. Chem.* **2007**, *31*, 1899–1906; d) B. Bertino-Ghera, F. Perret, B. Fenet, H. Parrot-Lopéz, *J. Org. Chem.* **2008**, *73*, 7317–7326.
[10] K. T. Lim, H. S. Ganapathy, M. Y. Lee, H. Yuvaraj, W.-K. Lee, H. Heon, *J. Fluorine Chem.* **2006**, *127*, 730–735.
[11] For an early example, see: A. K. Chatterjee, J. P. Morgan, M. Scholl, R. H. Grubbs, *J. Am. Chem. Soc.* **2000**, *122*, 3783–3784.
[12] S. Imhof, S. Randl, S. Blechert, *Chem. Commun.* **2001**, 1692–1693.
[13] B. B. Ghera, F. Fache, H. Parrot-Lopez, *Tetrahedron* **2006**, *62*, 4807–4813.
[14] B. Eignerová, M. Dračínský, M. Kotora, *Eur. J. Org. Chem.* **2008**, 4493–4499.
[15] B. Eignerová, B. Slavíková, M. Buděšínský, M. Dračínský, B. Klepetářová, E. Šťastná, M. Kotora, *J. Med. Chem.* **2009**, *52*, 5753–5757.
[16] B. Eignerová, Z. Janoušek, M. Kotora, *Synlett* **2010**, 885–887.
[17] J. Jindřich, I. Tišlerová, *J. Org. Chem.* **2005**, *70*, 9054–9055.
[18] Its preparation was reported, but no characterization was given: S. Hanessian, A. Benali, C. Laferriere, *J. Org. Chem.* **1995**, *60*, 4786–4797.
[19] J. Jindrich, J. Pitha, B. Lindberg, P. Seffers, K. Harata, *Carbohydr. Res.* **1995**, *266*, 75–80.
[20] A. L. Maksimov, D. A. Sakharov, T. Y. Filippova, A. Y. Zhuchkova, E. A. Karakhanov, *Ind. Eng. Chem. Res.* **2005**, *44*, 8644–8653.
[21] a) P. Schwab, R. H. Grubbs, J. W. Ziller, *J. Am. Chem. Soc.* **1996**, *118*, 100–111; b) T. T. Trnka, R. H. Grubbs, *Acc. Chem. Res.* **2001**, *34*, 18–29.

[22] a) S. B. Garber, J. S. Kingsbury, B. L. Gray, A. L. Hoveyda, *J. Am. Chem. Soc.* **2000**, *122*, 8168–8179; b) S. Gessler, S. Randl, S. Blechert, *Tetrahedron Lett.* **2000**, *41*, 9973–9976.
[23] O. F. Silva, M. A. Fernández, S. L. Pennie, R. R. Gil, R. H. de Rossi, *Langmuir* **2008**, *24*, 3718–3726.
[24] H. Zhang, W. An, Z. Liu, A. Hao, J. Hao, J. Shen, X. Zhao, H. Sun, L. Sun, *Carbohydr. Res.* **2010**, *345*, 87–96.
[25] Y. He, P. Fu, X. Shen, H. Gao, *Micron* **2008**, *39*, 495–516.
Received: June 5, 2010
Published Online: September 21, 2010

